Storypoint Prediction - datamanagement

September 14, 2024

1 Storypoint Prediction: Regression Approach

1.1 Preparation

[66]:
```
import os
import json
import random

import matplotlib.pyplot as plt
import numpy as np
import pandas as pd
import seaborn as sns
from scipy.sparse import csr_matrix, hstack, vstack

from sklearn.pipeline import Pipeline
from sklearn.preprocessing import RobustScaler
from sklearn.metrics import mean_squared_error, r2_score, mean_absolute_error,␣
 ↪f1_score, precision_score, recall_score, accuracy_score
from sklearn.feature_extraction.text import CountVectorizer
from sklearn.model_selection import learning_curve, validation_curve
from trainer import GridSearchCVTrainer

#['appceleratorstudio', 'aptanastudio', 'bamboo', 'clover',
# 'datamanagement', 'duracloud', 'jirasoftware', 'mesos',
# 'moodle', 'mule', 'mulestudio', 'springxd',
# 'talenddataquality', 'talendesb', 'titanium', 'usergrid']
project_name = 'datamanagement'
```

1.1.1 Plot learning curve

[67]:
```
def plot_learning_curve(estimator, title, X, y, ylim=None, cv=None,
                        n_jobs=-1, train_sizes=np.linspace(.1, 1.0, 10)):
    plt.figure()        # Create new figure
    plt.title(title)    # Set title of the figure

    # Set y-axis limits: ylim=(min, max)
    if ylim is not None:
        plt.ylim(*ylim)
```

```
    plt.xlabel("Training examples")  # Set x-axis label
    plt.ylabel("Score")               # Set y-axis label

    # Generate learning curve data
    train_sizes, train_scores, test_scores = learning_curve(
        estimator, X, y, cv=cv, n_jobs=n_jobs, train_sizes=train_sizes,␣
↪scoring='neg_mean_squared_error')

    train_scores_mean = np.mean(train_scores, axis=1)  # Calculate mean of␣
↪training scores
    train_scores_std = np.std(train_scores, axis=1)    # Calculate standard␣
↪deviation of training scores
    test_scores_mean = np.mean(test_scores, axis=1)    # Calculate mean of test␣
↪scores
    test_scores_std = np.std(test_scores, axis=1)      # Calculate standard␣
↪deviation of test scores

    plt.grid()  # Display grid

    # Fill the area between the mean training score and the mean +/- std␣
↪training score
    plt.fill_between(train_sizes, train_scores_mean - train_scores_std,
                     train_scores_mean + train_scores_std, alpha=0.1,
                     color="r")

    # Fill the area between the mean test score and the mean +/- std test score
    plt.fill_between(train_sizes, test_scores_mean - test_scores_std,
                    test_scores_mean + test_scores_std, alpha=0.1, color="g")

    # Plot mean training score as points
    plt.plot(train_sizes, train_scores_mean, 'o-', color="r",
             label="Training score")
    # Plot mean test score as points
    plt.plot(train_sizes, test_scores_mean, 'o-', color="g",
             label="Validation score")

    plt.legend(loc="best")  # Display legend
    return plt
```

1.1.2 Plot validation curve

[68]:
```
def plot_validation_curve(estimator, title, X, y, param_name, param_range,
                          y_lim=None, cv=10, n_jobs=-1):
    train_scores, val_scores = validation_curve(estimator=estimator, X=X, y=y,
                                                param_name=param_name,␣
↪param_range=param_range,
```

```
                                                      cv=cv, n_jobs=n_jobs,␣
↪scoring='neg_mean_squared_error')

    # Calculate mean and standard deviation of training and validation scores
    train_mean = np.mean(train_scores, axis=1)
    tran_std = np.std(train_scores, axis=1)
    val_mean = np.mean(val_scores, axis=1)
    val_std = np.std(val_scores, axis=1)
    print(val_mean)

    # Plot train scores
    plt.plot(param_range, train_mean, color='r', marker='o', markersize=5,␣
↪label='Training score')
    plt.fill_between(param_range, train_mean + tran_std, train_mean - tran_std,␣
↪alpha=0.15, color='r')

    # Plot validation scores
    plt.plot(param_range, val_mean, color='g', linestyle='--', marker='s',␣
↪markersize=5, label='Validation score')
    plt.fill_between(param_range, val_mean + val_std, val_mean - val_std,␣
↪alpha=0.15, color='g')

    plt.title(title)        # Set title of the plot
    plt.grid()              # Display grid
    plt.xscale('log')       # Set x-axis scale to log
    plt.legend(loc='best')  # Display legend
    plt.xlabel('Parameter') # Set x-axis label
    plt.ylabel('Score')     # Set y-axis label

    # Set y-axis limits
    if y_lim != None:
        plt.ylim(y_lim)

    return plt
```

1.1.3 Evaluate model

[69]:
```
def evaluate_model(model, model_name, X_test, y_test, y_logscale=False,␣
↪save_directory=None):
    y_pred = model.predict(X_test)
    if(y_logscale):
        y_pred = np.exp(y_pred)

    lines = [model_name + '\'s evaluation results:']

    mse = mean_squared_error(y_test, y_pred)
```

```
    rmse = np.sqrt(mse)
    mae = mean_absolute_error(y_test, y_pred)
    r2 = r2_score(y_test, y_pred)

    lines.append(f' - Mean squared error:      {mse:.4f}')
    lines.append(f' - Root mean squared error: {rmse:.4f}')
    lines.append(f' - Mean absolute error:     {mae:.4f}')
    lines.append(f' - R2 error:                {r2:.4f}')

    y_pred = np.round(y_pred).astype(int)
    f1 = f1_score(y_test, y_pred, average='weighted')
    precision = precision_score(y_test, y_pred, average='weighted',␣
↪zero_division=0)
    recall = recall_score(y_test, y_pred, average='weighted', zero_division=0)
    accuracy = accuracy_score(y_test, y_pred)

    lines.append(f' - F1 score:                {f1:.4f}')
    lines.append(f' - Precision:               {precision:.4f}')
    lines.append(f' - Recall:                  {recall:.4f}')
    lines.append(f' - Accuracy:                {accuracy:.4f}')
    lines.append('--------------------------------------------------')
    lines.append('')

    # Save to file

    if(save_directory != None):
        filename = save_directory + project_name + '.txt'
        directory = os.path.dirname(filename)
        if not os.path.exists(directory):
            os.makedirs(directory)
        with open(filename, 'a') as f:
            for line in lines:
                print(line)
                f.write(line + '\n')
    else:
        for line in lines:
            print(line)
```

1.1.4 Set random seed

[70]:
```
# Set random seed for numpy
np.random.seed(42)

# Set random seed for random
random.seed(42)

# Set random seed for os
```

```
os.environ['PYTHONHASHSEED'] = '42'
```

1.2 Dataset set-up

1.2.1 Bag of Words preprocessing

This is a Bag of Words preprocess approach. I will use 2 CountVectorizer from sklearn to change title and description to two 2 vectors and then concatenate them together. In the rest of this notebook, I will use cross-validation instead hold-out. Therefore, I will join the validation set with training set.

[71]:
```
# Import and remove NaN value


data_train = pd.concat([pd.read_csv('data/' + project_name + '/' + project_name␣
 ↪+ '_train.csv'),
                        pd.read_csv('data/' + project_name + '/' + project_name␣
 ↪+ '_valid.csv')])
data_test = pd.read_csv('data/' + project_name + '/' + project_name + '_test.
 ↪csv')

data_train['description'].replace(np.nan, '', inplace=True)
data_test['description'].replace(np.nan, '', inplace=True)

# Vectorize title
title_vectorizer = CountVectorizer(ngram_range=(1, 2), min_df=2)
title_vectorizer.fit(pd.concat([data_train['title'], data_test['title']]))

# Vectorize description
description_vectorizer = CountVectorizer(ngram_range=(1, 2), min_df=2)
description_vectorizer.fit(pd.concat([data_train['description'],␣
 ↪data_test['description']]))


X_train = hstack([title_vectorizer.transform(data_train['title']).astype(float),
                  description_vectorizer.transform(data_train['description']).
 ↪astype(float),
                  data_train['title'].apply(lambda x : len(x)).to_numpy().
 ↪reshape(-1, 1),
                  data_train['description'].apply(lambda x : len(x)).to_numpy().
 ↪reshape(-1, 1)
                ])

y_train = data_train['storypoint'].to_numpy().astype(float)

X_test = hstack([title_vectorizer.transform(data_test['title']).astype(float),
```

```
                   description_vectorizer.transform(data_test['description']).
 ↪astype(float),
                   data_test['title'].apply(lambda x : len(x)).to_numpy().
 ↪reshape(-1, 1),
                   data_test['description'].apply(lambda x : len(x)).to_numpy().
 ↪reshape(-1, 1)
                 ])

y_test = data_test['storypoint'].to_numpy().astype(float)
```

[72]:
```
print('Check training dataset\'shape:', X_train.shape, y_train.shape)
print('Check testing dataset\'shape:', X_test.shape, y_test.shape)
```

```
Check training dataset'shape: (3627, 18988) (3627,)
Check testing dataset'shape: (403, 18988) (403,)
```

I will use log-scale the label to get a normal distribution of it.

[73]:
```
y_train_log = np.log(y_train)
```

1.2.2 doc2vec preprocessing

This process is already prepared so I only need to import the thing

[74]:
```
# data_train = pd.concat([pd.read_csv('doc2vec/' + project_name + '/' +␣
 ↪project_name + '_train.csv'),
#                         pd.read_csv('doc2vec/' + project_name + '/' +␣
 ↪project_name + '_valid.csv')])
# data_test = pd.read_csv('doc2vec/' + project_name + '/' + project_name +␣
 ↪'_test.csv')

# X_train = np.vstack(data_train['doc2vec'].apply(lambda x: np.fromstring(x[1:
 ↪-1], sep=' ')).to_numpy())
# y_train = data_train['storypoint'].to_numpy().astype(int)

# X_test = np.vstack(data_test['doc2vec'].apply(lambda x: np.fromstring(x[1:
 ↪-1], sep=' ')).to_numpy())
# y_test = data_test['storypoint'].to_numpy().astype(int)
```

Check shape of the datasets

[75]:
```
# print('Check training dataset\'shape:', X_train.shape, y_train.shape)
# print('Check testing dataset\'shape:', X_test.shape, y_test.shape)
```

[76]:
```
# y_train_log = np.log(y_train)
```

1.3 Model training

1.3.1 Linear Regressor

[77]:
```
from sklearn.linear_model import ElasticNet, Ridge
```

Ridge

[78]:
```
dict_param = {
    'alpha': [.0001, .001, .01, .1, 1, 10, 100, 1000, 10000],
    'random_state': [42]
}
```

[79]:
```
grid_search = GridSearchCVTrainer(name='Ridge', model=Ridge(),␣
 ↪param_grid=dict_param,
                                  cv=5, n_jobs=5, directory='settings/BoW/' +␣
 ↪project_name + '/')
grid_search.load_if_exists()
grid_search.fit(X_train, y_train_log)

ridge_model = grid_search.best_estimator_
ridge_model.fit(X_train, y_train_log)
```

```
0it [00:00, ?it/s]
```

[79]:
```
Ridge(alpha=100, random_state=42)
```

[80]:
```
evaluate_model(ridge_model, 'Ridge model', X_test, y_test, y_logscale=True,␣
 ↪save_directory='results/BoW/')
```

```
Ridge model's evaluation results:
 - Mean squared error:      66.9339
 - Root mean squared error: 8.1813
 - Mean absolute error:     3.8448
 - R2 error:                0.3220
 - F1 score:                0.1009
 - Precision:               0.2107
 - Recall:                  0.1141
 - Accuracy:                0.1141
--------------------------------------------------
```

[81]:
```
ridge_model.get_params()
```

[81]:
```
{'alpha': 100,
 'copy_X': True,
 'fit_intercept': True,
 'max_iter': None,
 'positive': False,
 'random_state': 42,
```

```
 'solver': 'auto',
 'tol': 0.0001}
```

Elastic net:

[82]:
```
dict_param['l1_ratio'] = [.2, .4, .6, .8, 1]
dict_param['max_iter'] = [5000]
```

[83]:
```
grid_search = GridSearchCVTrainer(name='Elastic Net', model=ElasticNet(),␣
 ↪param_grid=dict_param,
                                  cv=5, n_jobs=5, directory='settings/BoW/' +␣
 ↪project_name + '/')
grid_search.load_if_exists()
grid_search.fit(X_train, y_train_log)

elastic_model = grid_search.best_estimator_
elastic_model.fit(X_train, y_train_log)
```

```
0it [00:00, ?it/s]
```

[83]:
```
ElasticNet(alpha=0.01, l1_ratio=0.2, max_iter=5000, random_state=42)
```

[84]:
```
evaluate_model(elastic_model, 'Elastic Net model', X_test, y_test,␣
 ↪y_logscale=True, save_directory='results/BoW/')
```

```
Elastic Net model's evaluation results:
 - Mean squared error:      64.2974
 - Root mean squared error: 8.0186
 - Mean absolute error:     3.8291
 - R2 error:                0.3487
 - F1 score:                0.1002
 - Precision:               0.1986
 - Recall:                  0.1191
 - Accuracy:                0.1191
--------------------------------------------------
```

[85]:
```
elastic_model.get_params()
```

[85]:
```
{'alpha': 0.01,
 'copy_X': True,
 'fit_intercept': True,
 'l1_ratio': 0.2,
 'max_iter': 5000,
 'positive': False,
 'precompute': False,
 'random_state': 42,
 'selection': 'cyclic',
 'tol': 0.0001,
```

```
 'warm_start': False}
```

Choose final linear regressor model:

[86]:
```
if mean_squared_error(y_test, np.exp(ridge_model.predict(X_test))) <\
   mean_squared_error(y_test, np.exp(elastic_model.predict(X_test))):
    linear_model = ridge_model
else:
    linear_model = elastic_model
```

1.3.2 Support Vector Regressor

[87]:
```
from sklearn.svm import SVR
```

[88]:
```
dict_param = {
    'C': [.0001, .001, .01, .1, 1, 10, 100, 1000, 10000],
    'epsilon': [.0001, .001, .01, .1, 1, 10, 100, 1000, 10000],
    'gamma': np.logspace(-9, 3, 13),
    'kernel': ['rbf']
}
```

[89]:
```
grid_search = GridSearchCVTrainer(name="Support Vector Regressor", model=SVR(),␣
 ↪param_grid=dict_param,
                                  cv=5, n_jobs=5, directory='settings/BoW/' +␣
 ↪project_name + '/')
grid_search.load_if_exists()
grid_search.fit(X_train, y_train_log)

svr_model = grid_search.best_estimator_
svr_model.fit(X_train, y_train_log)
```

```
There is no checkpoint file for this model.
```

```
100%|      | 1053/1053 [35:54<00:00,  2.05s/it]
```

[89]:
```
SVR(C=1000, gamma=1e-05)
```

[90]:
```
evaluate_model(svr_model, 'SVR model', X_test, y_test, y_logscale=True,␣
 ↪save_directory='results/BoW/')
```

```
SVR model's evaluation results:
 - Mean squared error:      62.3287
 - Root mean squared error: 7.8949
 - Mean absolute error:     3.7603
 - R2 error:                0.3687
 - F1 score:                0.1418
 - Precision:               0.3011
 - Recall:                  0.1414
 - Accuracy:                0.1414
```

----

[91]:
```
svr_model.get_params()
```

[91]:
```
{'C': 1000,
 'cache_size': 200,
 'coef0': 0.0,
 'degree': 3,
 'epsilon': 0.1,
 'gamma': 1e-05,
 'kernel': 'rbf',
 'max_iter': -1,
 'shrinking': True,
 'tol': 0.001,
 'verbose': False}
```

1.3.3 Random Forest Regressor

[92]:
```
from sklearn.ensemble import RandomForestRegressor
```

[93]:
```
dict_param = {
    'max_depth' : [1000, 2000, 5000],
    'min_samples_split': [25, 200, 1000],
    'min_samples_leaf': [1, 2, 3, 4],
    'max_features': [50, 100, 200],
    'n_estimators': [1024],
    'random_state': [42]
}
```

[94]:
```
grid_search = GridSearchCVTrainer(name="Random Forest Regressor",
                                  model=RandomForestRegressor(),
                                  param_grid=dict_param, cv = 5, n_jobs=-1,
                                  directory='settings/BoW/' + project_name + '/
 ↪')
grid_search.load_if_exists()
grid_search.fit(X_train, y_train_log)

rfr_model = grid_search.best_estimator_
rfr_model.fit(X_train, y_train_log)
```

```
0it [00:00, ?it/s]
```

[94]:
```
RandomForestRegressor(max_depth=1000, max_features=200, min_samples_split=25,
                      n_estimators=1024, random_state=42)
```

[95]:
```
evaluate_model(rfr_model, 'Random Forest model', X_test, y_test,␣
 ↪y_logscale=True, save_directory='results/BoW/')
```

```
Random Forest model's evaluation results:
 - Mean squared error:      71.4102
 - Root mean squared error: 8.4505
 - Mean absolute error:     3.5437
 - R2 error:                0.2767
 - F1 score:                0.0900
 - Precision:               0.3256
 - Recall:                  0.1017
 - Accuracy:                0.1017
-------------------------------------------------
```

[96]:

```
rfr_model.get_params()
```

[96]:

```
{'bootstrap': True,
 'ccp_alpha': 0.0,
 'criterion': 'squared_error',
 'max_depth': 1000,
 'max_features': 200,
 'max_leaf_nodes': None,
 'max_samples': None,
 'min_impurity_decrease': 0.0,
 'min_samples_leaf': 1,
 'min_samples_split': 25,
 'min_weight_fraction_leaf': 0.0,
 'monotonic_cst': None,
 'n_estimators': 1024,
 'n_jobs': None,
 'oob_score': False,
 'random_state': 42,
 'verbose': 0,
 'warm_start': False}
```

1.3.4 XGBoost

[97]:

```
from xgboost import XGBRegressor
```

[98]:

```
dict_param = {
    'eta' : np.linspace(0.01, 0.2, 3),
    'gamma': np.logspace(-2, 2, 5),
    'max_depth': np.asarray([3, 5, 7, 9]).tolist(),
    'min_child_weight': np.logspace(-2, 2, 5),
    'subsample': np.asarray([0.5, .1]),
    'reg_alpha': np.asarray([0.0, 0.05]),
    'n_estimators': np.asarray([10, 20, 50, 100]).tolist(),
    'random_state': [42]
}
```

[99]:
```
grid_search = GridSearchCVTrainer(name='XGBoost␣
↪Regressor',model=XGBRegressor(), param_grid=dict_param,
                                  cv = 5, n_jobs=2, directory='settings/BoW/' +␣
↪project_name + '/')
grid_search.load_if_exists()
grid_search.fit(X_train, y_train_log)

xgb_model = grid_search.best_estimator_
xgb_model.fit(X_train, y_train_log)
```

```
0it [00:00, ?it/s]
```

[99]:
```
XGBRegressor(base_score=None, booster=None, callbacks=None,
             colsample_bylevel=None, colsample_bynode=None,
             colsample_bytree=None, device=None, early_stopping_rounds=None,
             enable_categorical=False, eta=0.105, eval_metric=None,
             feature_types=None, gamma=1.0, grow_policy=None,
             importance_type=None, interaction_constraints=None,
             learning_rate=None, max_bin=None, max_cat_threshold=None,
             max_cat_to_onehot=None, max_delta_step=None, max_depth=9,
             max_leaves=None, min_child_weight=0.01, missing=nan,
             monotone_constraints=None, multi_strategy=None, n_estimators=100,
             n_jobs=None, num_parallel_tree=None, …)
```

[100]:
```
evaluate_model(xgb_model, 'XGBoost Regressor model', X_test, y_test,␣
↪y_logscale=True, save_directory='results/BoW/')
```

```
XGBoost Regressor model's evaluation results:
 - Mean squared error:      65.3111
 - Root mean squared error: 8.0815
 - Mean absolute error:     3.9848
 - R2 error:                0.3385
 - F1 score:                0.1199
 - Precision:               0.3744
 - Recall:                  0.1241
 - Accuracy:                0.1241
-------------------------------------------------
```

[101]:
```
xgb_model.get_params()
```

[101]:
```
{'objective': 'reg:squarederror',
 'base_score': None,
 'booster': None,
 'callbacks': None,
 'colsample_bylevel': None,
 'colsample_bynode': None,
 'colsample_bytree': None,
```

```
'device': None,
'early_stopping_rounds': None,
'enable_categorical': False,
'eval_metric': None,
'feature_types': None,
'gamma': 1.0,
'grow_policy': None,
'importance_type': None,
'interaction_constraints': None,
'learning_rate': None,
'max_bin': None,
'max_cat_threshold': None,
'max_cat_to_onehot': None,
'max_delta_step': None,
'max_depth': 9,
'max_leaves': None,
'min_child_weight': 0.01,
'missing': nan,
'monotone_constraints': None,
'multi_strategy': None,
'n_estimators': 100,
'n_jobs': None,
'num_parallel_tree': None,
'random_state': 42,
'reg_alpha': 0.0,
'reg_lambda': None,
'sampling_method': None,
'scale_pos_weight': None,
'subsample': 0.5,
'tree_method': None,
'validate_parameters': None,
'verbosity': None,
'eta': 0.105}
```

1.3.5 LightGBM

[102]:
```python
from lightgbm import LGBMRegressor
from sklearn.model_selection import ParameterSampler
```

[103]:
```python
dict_param = {
    'n_estimator': [10, 20, 50, 100, 200, 500],
    'max_depth': np.asarray([5, 7, 9, 11, 13]).tolist(),
    'num_leaves': ((np.power(2, np.asarray([5, 7, 9, 11, 13])) - 1) * (0.55 +
 ↪(0.65 - 0.55) * np.random.rand(5))).astype(int).tolist(),
    'min_data_in_leaf': np.linspace(100, 1000, 4).astype(int).tolist(),
    'feature_fraction': np.linspace(0.6, 1, 3),
    'bagging_fraction': np.linspace(0.6, 1, 3),
```

```
    'learning_rate': [0.01],
    'verbose': [-1],
    'random_state': [42]
}

def custom_sampler(param_grid):
    for params in ParameterSampler(param_grid, n_iter=1e9):
        range_num_leaves = ((0.5 * (2**params['max_depth'] - 1)), (0.7 *␣
↪(2**params['max_depth']) - 1))
        if(range_num_leaves[0] <= params['num_leaves'] <= range_num_leaves[1]):
            for key, value in params.items():
                params[key] = [value]
            yield params
```

[104]:

```
grid_search = GridSearchCVTrainer(name='LightGBM Regressor',␣
↪model=LGBMRegressor(),
                                param_grid=list(custom_sampler(dict_param)), cv␣
↪= 5, n_jobs=1,
                                directory='settings/BoW/' + project_name + '/')
grid_search.load_if_exists()
grid_search.fit(X_train, y_train_log)

lgbmr_model = grid_search.best_estimator_
lgbmr_model.fit(X_train, y_train_log)
```

```
c:\Users\aupho\AppData\Local\Programs\Python\Python311\Lib\site-
packages\sklearn\model_selection\_search.py:320: UserWarning: The total space of
parameters 5400 is smaller than n_iter=1000000000. Running 5400 iterations. For
exhaustive searches, use GridSearchCV.
  warnings.warn(
0it [00:00, ?it/s]
```

[104]:

```
LGBMRegressor(bagging_fraction=0.6, feature_fraction=1.0, learning_rate=0.01,
              max_depth=11, min_data_in_leaf=100, n_estimator=10,
              num_leaves=1248, random_state=42, verbose=-1)
```

[105]:

```
evaluate_model(lgbmr_model, 'LightGBM regressor model', X_test, y_test,␣
↪y_logscale=True,  save_directory='results/BoW/')
```

```
LightGBM regressor model's evaluation results:
 - Mean squared error:      93.0929
 - Root mean squared error: 9.6485
 - Mean absolute error:     4.0668
 - R2 error:                0.0571
 - F1 score:                0.0860
 - Precision:               0.0671
 - Recall:                  0.1563
 - Accuracy:                0.1563
```

```
------------------------------------------------

c:\Users\aupho\AppData\Local\Programs\Python\Python311\Lib\site-
packages\lightgbm\basic.py:1218: UserWarning: Converting data to scipy sparse
matrix.
  _log_warning("Converting data to scipy sparse matrix.")
```

[106]:
```
lgbmr_model.get_params()
```

[106]:
```
{'boosting_type': 'gbdt',
 'class_weight': None,
 'colsample_bytree': 1.0,
 'importance_type': 'split',
 'learning_rate': 0.01,
 'max_depth': 11,
 'min_child_samples': 20,
 'min_child_weight': 0.001,
 'min_split_gain': 0.0,
 'n_estimators': 100,
 'n_jobs': None,
 'num_leaves': 1248,
 'objective': None,
 'random_state': 42,
 'reg_alpha': 0.0,
 'reg_lambda': 0.0,
 'subsample': 1.0,
 'subsample_for_bin': 200000,
 'subsample_freq': 0,
 'verbose': -1,
 'n_estimator': 10,
 'min_data_in_leaf': 100,
 'feature_fraction': 1.0,
 'bagging_fraction': 0.6}
```

1.3.6 Stacked model:

[107]:
```
from mlxtend.regressor import StackingCVRegressor
```

Define component models:

[108]:
```
trained_models = [linear_model, svr_model, rfr_model, xgb_model, lgbmr_model]
```

Define blended model:

[109]:
```
stack_gen = StackingCVRegressor(regressors=tuple(trained_models),
                                meta_regressor=trained_models[np.
 ↪argmin([mean_squared_error(np.exp(model.predict(X_test)), y_test) for model␣
 ↪in trained_models])],
```

```
                                     use_features_in_secondary=True, n_jobs=-1,␣
 ↪random_state=42)
print(stack_gen)
```

```
StackingCVRegressor(meta_regressor=SVR(C=1000, gamma=1e-05), n_jobs=-1,
                    random_state=42,
                    regressors=(ElasticNet(alpha=0.01, l1_ratio=0.2,
                                           max_iter=5000, random_state=42),
                                SVR(C=1000, gamma=1e-05),
                                RandomForestRegressor(max_depth=1000,
                                                      max_features=200,
                                                      min_samples_split=25,
                                                      n_estimators=1024,
                                                      random_state=42),
                                XGBRegressor(base_score=None, booster=None,
                                             callbacks=N…
                                             max_leaves=None,
                                             min_child_weight=0.01, missing=nan,
                                             monotone_constraints=None,
                                             multi_strategy=None,
                                             n_estimators=100, n_jobs=None,
                                             num_parallel_tree=None, …),
                                LGBMRegressor(bagging_fraction=0.6,
                                              feature_fraction=1.0,
                                              learning_rate=0.01, max_depth=11,
                                              min_data_in_leaf=100,
                                              n_estimator=10, num_leaves=1248,
                                              random_state=42, verbose=-1)),
                    use_features_in_secondary=True)
```

```
c:\Users\aupho\AppData\Local\Programs\Python\Python311\Lib\site-
packages\lightgbm\basic.py:1218: UserWarning: Converting data to scipy sparse
matrix.
  _log_warning("Converting data to scipy sparse matrix.")
```

[110]:
```
stack_gen.fit(X_train, y_train_log)
```

[110]:
```
StackingCVRegressor(meta_regressor=SVR(C=1000, gamma=1e-05), n_jobs=-1,
                    random_state=42,
                    regressors=(ElasticNet(alpha=0.01, l1_ratio=0.2,
                                           max_iter=5000, random_state=42),
                                SVR(C=1000, gamma=1e-05),
                                RandomForestRegressor(max_depth=1000,
                                                      max_features=200,
                                                      min_samples_split=25,
                                                      n_estimators=1024,
                                                      random_state=42),
                                XGBRegressor(base_score=None, booster=None,
```

```
                                                     callbacks=N…
                                                     max_leaves=None,
                                                     min_child_weight=0.01, missing=nan,
                                                     monotone_constraints=None,
                                                     multi_strategy=None,
                                                     n_estimators=100, n_jobs=None,
                                                     num_parallel_tree=None, …),
                                      LGBMRegressor(bagging_fraction=0.6,
                                                    feature_fraction=1.0,
                                                    learning_rate=0.01, max_depth=11,
                                                    min_data_in_leaf=100,
                                                    n_estimator=10, num_leaves=1248,
                                                    random_state=42, verbose=-1)),
                         use_features_in_secondary=True)
```

[111]:
```
evaluate_model(stack_gen, 'Stacking model', X_test, y_test, y_logscale=True,␣
  ↪save_directory='results/BoW/')
```

```
c:\Users\aupho\AppData\Local\Programs\Python\Python311\Lib\site-
packages\lightgbm\basic.py:1218: UserWarning: Converting data to scipy sparse
matrix.
  _log_warning("Converting data to scipy sparse matrix.")
```

```
Stacking model's evaluation results:
 - Mean squared error:      62.2274
 - Root mean squared error: 7.8884
 - Mean absolute error:     3.8913
 - R2 error:                0.3697
 - F1 score:                0.1727
 - Precision:               0.3276
 - Recall:                  0.1464
 - Accuracy:                0.1464
--------------------------------------------------
```

[112]:
```
stack_gen.get_params()
```

[112]:
```
{'cv': 5,
 'meta_regressor__C': 1000,
 'meta_regressor__cache_size': 200,
 'meta_regressor__coef0': 0.0,
 'meta_regressor__degree': 3,
 'meta_regressor__epsilon': 0.1,
 'meta_regressor__gamma': 1e-05,
 'meta_regressor__kernel': 'rbf',
 'meta_regressor__max_iter': -1,
 'meta_regressor__shrinking': True,
 'meta_regressor__tol': 0.001,
```

```
 'meta_regressor__verbose': False,
 'meta_regressor': SVR(C=1000, gamma=1e-05),
 'multi_output': False,
 'n_jobs': -1,
 'pre_dispatch': '2*n_jobs',
 'random_state': 42,
 'refit': True,
 'regressors': (ElasticNet(alpha=0.01, l1_ratio=0.2, max_iter=5000,
random_state=42),
  SVR(C=1000, gamma=1e-05),
  RandomForestRegressor(max_depth=1000, max_features=200, min_samples_split=25,
                        n_estimators=1024, random_state=42),
  XGBRegressor(base_score=None, booster=None, callbacks=None,
               colsample_bylevel=None, colsample_bynode=None,
               colsample_bytree=None, device=None, early_stopping_rounds=None,
               enable_categorical=False, eta=0.105, eval_metric=None,
               feature_types=None, gamma=1.0, grow_policy=None,
               importance_type=None, interaction_constraints=None,
               learning_rate=None, max_bin=None, max_cat_threshold=None,
               max_cat_to_onehot=None, max_delta_step=None, max_depth=9,
               max_leaves=None, min_child_weight=0.01, missing=nan,
               monotone_constraints=None, multi_strategy=None, n_estimators=100,
               n_jobs=None, num_parallel_tree=None, …),
  LGBMRegressor(bagging_fraction=0.6, feature_fraction=1.0, learning_rate=0.01,
                max_depth=11, min_data_in_leaf=100, n_estimator=10,
                num_leaves=1248, random_state=42, verbose=-1)),
 'shuffle': True,
 'store_train_meta_features': False,
 'use_features_in_secondary': True,
 'verbose': 0,
 'elasticnet': ElasticNet(alpha=0.01, l1_ratio=0.2, max_iter=5000,
random_state=42),
 'svr': SVR(C=1000, gamma=1e-05),
 'randomforestregressor': RandomForestRegressor(max_depth=1000,
max_features=200, min_samples_split=25,
                       n_estimators=1024, random_state=42),
 'xgbregressor': XGBRegressor(base_score=None, booster=None, callbacks=None,
              colsample_bylevel=None, colsample_bynode=None,
              colsample_bytree=None, device=None, early_stopping_rounds=None,
              enable_categorical=False, eta=0.105, eval_metric=None,
              feature_types=None, gamma=1.0, grow_policy=None,
              importance_type=None, interaction_constraints=None,
              learning_rate=None, max_bin=None, max_cat_threshold=None,
              max_cat_to_onehot=None, max_delta_step=None, max_depth=9,
              max_leaves=None, min_child_weight=0.01, missing=nan,
              monotone_constraints=None, multi_strategy=None, n_estimators=100,
              n_jobs=None, num_parallel_tree=None, …),
```

```
 'lgbmregressor': LGBMRegressor(bagging_fraction=0.6, feature_fraction=1.0,
learning_rate=0.01,
               max_depth=11, min_data_in_leaf=100, n_estimator=10,
               num_leaves=1248, random_state=42, verbose=-1),
 'elasticnet__alpha': 0.01,
 'elasticnet__copy_X': True,
 'elasticnet__fit_intercept': True,
 'elasticnet__l1_ratio': 0.2,
 'elasticnet__max_iter': 5000,
 'elasticnet__positive': False,
 'elasticnet__precompute': False,
 'elasticnet__random_state': 42,
 'elasticnet__selection': 'cyclic',
 'elasticnet__tol': 0.0001,
 'elasticnet__warm_start': False,
 'svr__C': 1000,
 'svr__cache_size': 200,
 'svr__coef0': 0.0,
 'svr__degree': 3,
 'svr__epsilon': 0.1,
 'svr__gamma': 1e-05,
 'svr__kernel': 'rbf',
 'svr__max_iter': -1,
 'svr__shrinking': True,
 'svr__tol': 0.001,
 'svr__verbose': False,
 'randomforestregressor__bootstrap': True,
 'randomforestregressor__ccp_alpha': 0.0,
 'randomforestregressor__criterion': 'squared_error',
 'randomforestregressor__max_depth': 1000,
 'randomforestregressor__max_features': 200,
 'randomforestregressor__max_leaf_nodes': None,
 'randomforestregressor__max_samples': None,
 'randomforestregressor__min_impurity_decrease': 0.0,
 'randomforestregressor__min_samples_leaf': 1,
 'randomforestregressor__min_samples_split': 25,
 'randomforestregressor__min_weight_fraction_leaf': 0.0,
 'randomforestregressor__monotonic_cst': None,
 'randomforestregressor__n_estimators': 1024,
 'randomforestregressor__n_jobs': None,
 'randomforestregressor__oob_score': False,
 'randomforestregressor__random_state': 42,
 'randomforestregressor__verbose': 0,
 'randomforestregressor__warm_start': False,
 'xgbregressor__objective': 'reg:squarederror',
 'xgbregressor__base_score': None,
 'xgbregressor__booster': None,
```

```
'xgbregressor__callbacks': None,
'xgbregressor__colsample_bylevel': None,
'xgbregressor__colsample_bynode': None,
'xgbregressor__colsample_bytree': None,
'xgbregressor__device': None,
'xgbregressor__early_stopping_rounds': None,
'xgbregressor__enable_categorical': False,
'xgbregressor__eval_metric': None,
'xgbregressor__feature_types': None,
'xgbregressor__gamma': 1.0,
'xgbregressor__grow_policy': None,
'xgbregressor__importance_type': None,
'xgbregressor__interaction_constraints': None,
'xgbregressor__learning_rate': None,
'xgbregressor__max_bin': None,
'xgbregressor__max_cat_threshold': None,
'xgbregressor__max_cat_to_onehot': None,
'xgbregressor__max_delta_step': None,
'xgbregressor__max_depth': 9,
'xgbregressor__max_leaves': None,
'xgbregressor__min_child_weight': 0.01,
'xgbregressor__missing': nan,
'xgbregressor__monotone_constraints': None,
'xgbregressor__multi_strategy': None,
'xgbregressor__n_estimators': 100,
'xgbregressor__n_jobs': None,
'xgbregressor__num_parallel_tree': None,
'xgbregressor__random_state': 42,
'xgbregressor__reg_alpha': 0.0,
'xgbregressor__reg_lambda': None,
'xgbregressor__sampling_method': None,
'xgbregressor__scale_pos_weight': None,
'xgbregressor__subsample': 0.5,
'xgbregressor__tree_method': None,
'xgbregressor__validate_parameters': None,
'xgbregressor__verbosity': None,
'xgbregressor__eta': 0.105,
'lgbmregressor__boosting_type': 'gbdt',
'lgbmregressor__class_weight': None,
'lgbmregressor__colsample_bytree': 1.0,
'lgbmregressor__importance_type': 'split',
'lgbmregressor__learning_rate': 0.01,
'lgbmregressor__max_depth': 11,
'lgbmregressor__min_child_samples': 20,
'lgbmregressor__min_child_weight': 0.001,
'lgbmregressor__min_split_gain': 0.0,
'lgbmregressor__n_estimators': 100,
```

```
'lgbmregressor__n_jobs': None,
'lgbmregressor__num_leaves': 1248,
'lgbmregressor__objective': None,
'lgbmregressor__random_state': 42,
'lgbmregressor__reg_alpha': 0.0,
'lgbmregressor__reg_lambda': 0.0,
'lgbmregressor__subsample': 1.0,
'lgbmregressor__subsample_for_bin': 200000,
'lgbmregressor__subsample_freq': 0,
'lgbmregressor__verbose': -1,
'lgbmregressor__n_estimator': 10,
'lgbmregressor__min_data_in_leaf': 100,
'lgbmregressor__feature_fraction': 1.0,
'lgbmregressor__bagging_fraction': 0.6}
```